Report Number: TRA-065002-47-01A
Issue: A

Report on the Radio Testing of a Foster & Freeman Limited VSC90 With Respect to Specification FCC 47CFR 15.225

Test Date: 2024-09-26 to 2024-10-09

Tested by:	Digitally signed by Steven Hodgkinson DN: cn=Steven Hodgkinson, o=Element, ou=Radio, email=steven.hodgkinson@element.com, c=GB Date: 2024.12.03 09:47:42 Z	S Hodgkinson Radio Test Engineer
Written by:	Digitally signed by Steven Hodgkinson DN: cn=Steven Hodgkinson, o=Element, ou=Radio, email=steven.hodgkinson@element.com, c=GB Date: 2024.12.03 09:48:13 Z	P.P.S Garwell Radio Test Engineer
Approved by:	Digitally signed by John Charters Date: 2024.12.03 13:57:15 Z	J Charters Lab Manager
Date:	2024-11-02	

1 Revision Record

Issue	*Issue Date*	*Revision History*
A	2024-11-02	Original

2 Summary

Test Report Number:	TRA-065002-47-01A
Works Order Number:	TRA-065002-00
Purpose of Test:	USA: Testing of Radio Frequency Equipment per The Relevant Authorization Procedure of Chapter 47 of CFR (Code of Federal Regulations) Part 2, Subpart J.
Test Specification:	47CFR15.225
Equipment Under Test (EUT):	VSC90
FCC Identifier:	2BHQFVSCRFID
EUT Serial Number:	ALPHA-001
Manufacturer:	Foster & Freeman Limited
Address:	Vale Park Evesham Worcestershire WR11 1TD United Kingdom
Client Contact:	Alessandro Giusto ☎ 01386 240400 ✉ alessandro.giusto@fosterfreeman.com
Order Number:	TRA-065002-01
Test Date:	2024-09-26 to 2024-10-09
Tested By:	S Hodgkinson Element

2.1 Test Summary

Test Method and Description	*Requirement Clause* *47CFR15*	*Applicable to this Equipment*	*Result / Note*
Radiated Spurious Emissions, Below 30 MHz	15.225(d)	☒	*Pass*
Radiated Spurious Emissions	15.209	☒	*Pass*
AC Power Line Conducted Emissions	15.207	☒	*Pass*
Occupied Bandwidth	15.215(c)	☒	*Pass*
Field Strength of Fundamental	15.225(a), (b) and (c)	☒	*Pass*
Frequency Stability	15.225(e)	☒	*Pass*

General Notes:

The results contained in this report relate only to the items tested, in the condition at time of test, and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.

The apparatus was set up and exercised using the configurations, modes of operation and arrangements defined in this report only. Any modifications made are identified in Section 8 of this report.

Particular operating modes, apparatus monitoring methods and performance criteria required by the standards tested to have been performed except where identified in Section 5.2 of this test report (Deviations from Test Standards).

The decision rule for compliance is inherent within this specification. The measured value related to the corresponding limit is used to decide whether an equipment meets the requirements of the test specification.

The decision rule for compliance is not inherent within this specification and compliance is based on the customer requesting a simple acceptance rule based on understanding and acceptance of Elements Measurement Uncertainty values.

3 Contents

4 Introduction

This report TRA-065002-47-01A presents the results of the Radio testing on a Foster & Freeman Limited, VSC90 to specification 47CFR15 Radio Frequency Devices.

The testing was carried out for Foster & Freeman Limited by Element, at the address detailed below.

☒ Element Skelmersdale
Unit 1
Pendle Place
Skelmersdale
West Lancashire
WN8 9PN
UK

☐ Element Surrey Hills
Unit 15 B
Henley Business Park
Pirbright Road
Normandy
Guildford
GU3 2DX
UK

This report details the configuration of the equipment, the test methods used and any relevant modifications where appropriate.

All test and measurement equipment under the control of the laboratory and requiring calibration is subject to an established programme and procedures to control and maintain measurement standards. The quality management system meets the principles of ISO 9001, and has quality control procedures for monitoring the validity of tests undertaken. Records and sufficient detail are retained to establish an audit trail of calibration records relating to its test results for a defined period. Under control of the established calibration programme, key quantities or values of the test & measurement instrumentation are within specification and comply with the relevant traceable internationally recognised and appropriate standard specifications, which are ISO/IEC 17025:2017 accredited calibrated as such where these properties have a significant effect on results. Participation in inter-laboratory comparisons and proficiency testing ensures satisfactory correlation of results conform to Elements own procedures, as well as statistical techniques for analysis of test data providing the appropriate confidence in measurements.

FCC Site Listing:
The test laboratory is accredited for the above sites under the following US-UK MRA, Designation numbers.

Element Surrey Hills	UK2027
Element Skelmersdale	UK2020

The test site requirements of ANSI C63.4-2014 are met up to 1 GHz.

The test site SVSWR requirements of CISPR 16-1-4:2010 are met over the frequency range 1 GHz to 18 GHz.

5 Test Specifications

5.1 Normative References

- FCC 47 CFR Ch. I – Part 15 – Radio Frequency Devices
- ANSI C63.10-2013 – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- ANSI C63.4-2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
- KDB 174176 D01 Line Conducted FAQ v01r01 - AC Power-Line Conducted Emissions Frequently Asked Questions

5.2 Deviations from Test Standards

There were no deviations from the test standard.

6 Glossary of Terms

§	denotes a section reference from the standard, not this document
AC	Alternating Current
ANSI	American National Standards Institute
BW	bandwidth
C	Celsius
CFR	Code of Federal Regulations
CW	Continuous Wave
dB	decibel
dBm	dB relative to 1 milliwatt
DC	Direct Current
DSSS	Direct Sequence Spread Spectrum
EUT	Equipment Under Test
e.i.r.p.	Equivalent Isotropically Radiated Power
e.r.p.	Effective Radiated Power
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
Hz	hertz
IC	Industry Canada (now ISED)
ISED	Innovation, Science and Economic Development Canada
ITU	International Telecommunication Union
LBT	Listen Before Talk
m	metre
max	maximum
MIMO	Multiple Input and Multiple Output
min	minimum
MRA	Mutual Recognition Agreement
N/A	Not Applicable
PCB	Printed Circuit Board
PDF	Portable Document Format
Pt-mpt	Point-to-multipoint
Pt-pt	Point-to-point
RF	Radio Frequency
RH	Relative Humidity
RMS	Root Mean Square
Rx	receiver
s	second
SISO	Single Input and Single Output
SVSWR	Site Voltage Standing Wave Ratio
Tx	transmitter
UKAS	United Kingdom Accreditation Service
V	volt
W	watt
Ω	ohm

7 Equipment under Test

7.1 EUT Identification

- Name: VSC90
- Serial Number: ALPHA-001
- Model Number: Embedded PC variant
- Software Revision: Version 0.0.9.0 released on Sep 16 2024
- Build Level / Revision Number: Alpha Prototype

7.2 System Equipment

Equipment listed below forms part of the overall test setup and is required for equipment functionality and/or monitoring during testing. The compliance levels achieved in this report relate only to the EUT and not items given in the following list.

- *Dell U3223QE Ultrasharp 32 4K USB-C Monitor, serial number CN-09V7FK- WSL00-21R-780L.*
- *Keyboard (used to control VSC90*
- *Mouse (used to control VSC90)*

7.3 EUT Mode of Operation

7.3.1 Transmission

The mode of operation for transmitter tests was as follows…

The EUT was reading the RFID off a sample passport and cycling through its modes of operation.

7.4 EUT Radio Parameters

7.4.1 General

Frequency of Operation:	13.56 MHz
Modulation Type:	ASK
Channel Bandwidth:	N/A
Channel Spacing:	N/A
Nominal Supply Voltage:	110 Vac

7.4.2 Antenna

Type:	Differential input, loop antenna
Dimensions:	162mm x 222mm (outside of loop trace), 250mm x 230mm (PCB).
Number of Turns:	2

7.5 EUT Description

The EUT is a Video Spectral Comparator, containing a 13.56 MHz RFID radio.

This test report covers the testing of the 13.56 MHz radio only.

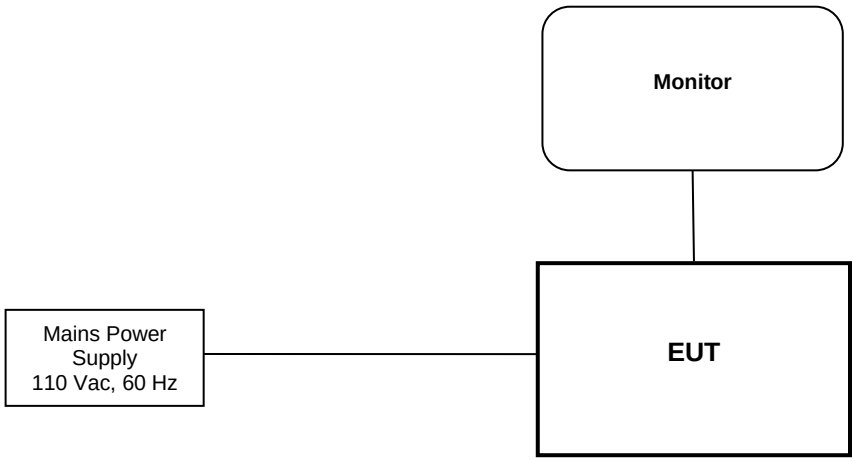
8 Modifications

No modifications were performed during this assessment.

9 EUT Test Setup

9.1 Block Diagram

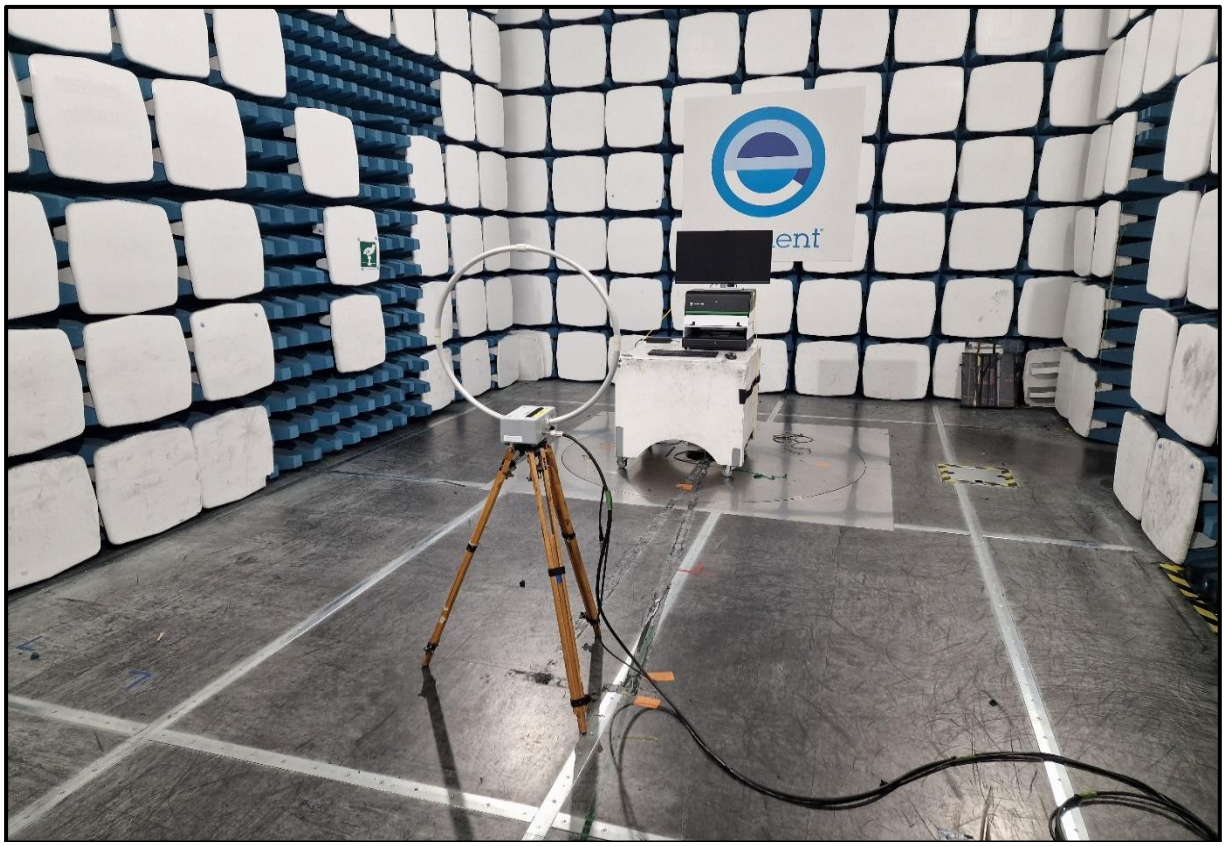
The following diagram shows basic EUT interconnections with cable type and cable lengths identified:



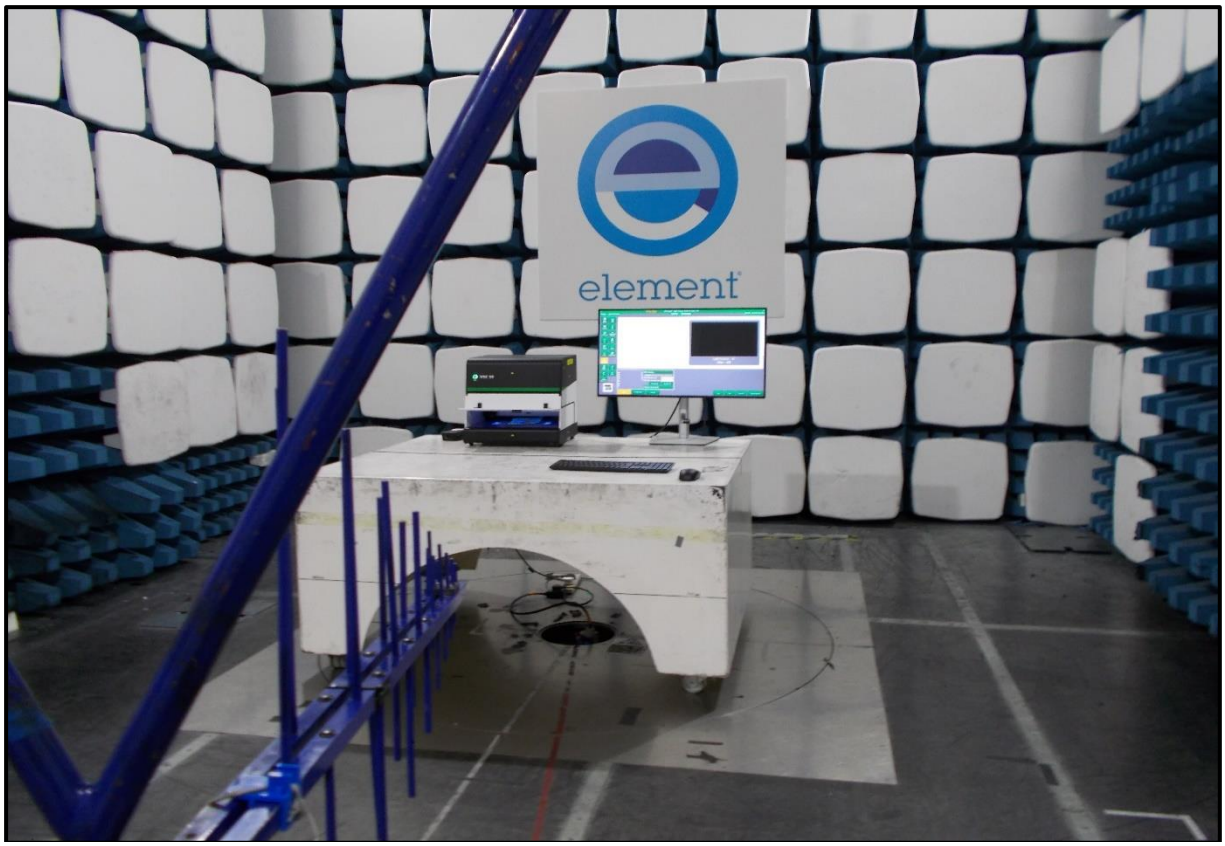
9.2 General Set-up Photographs

The following photographs shows basic EUT set-up:

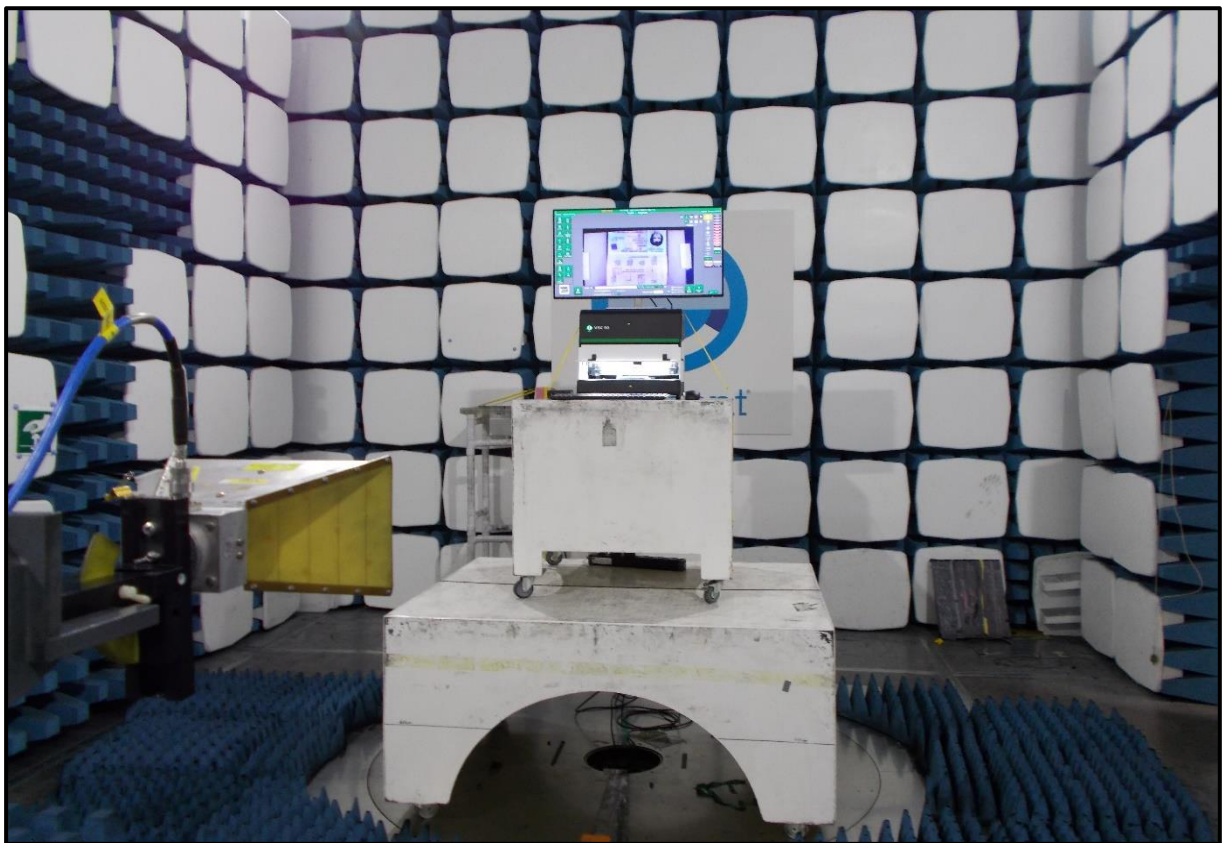
OATS



9 kHz to 30 MHz



30 MHz to 1 GHz



1 GHz to 7 GHz

9.3 Measurement Software

Where applicable, the following software was used to perform measurements contained within this report.

Element Emissions R5 (See Note)
Element Transmitter Bench Test (See Note)
ETS Lindgren EMPower V1.0.4.2

Note:

The version of the Element software used is recorded in the results sheets contained within this report.

10 General Technical Parameters

10.1 Normal Conditions

The VSC90 was tested under the normal environmental conditions of the test laboratory, except where otherwise stated. The normal power source applied was 110 Vac, 60 Hz, from the mains.

10.2 Varying Test Conditions

Variation of temperature is required to ensure stability of the declared fundamental frequency. During frequency error testing the following variations were made:

	Category	***Variation***
☒	Standard	-20 to +50 C in 10 degree steps
☐	Extended	

Variation of supply voltage is required to ensure stability of the declared output power and frequency. During carrier power and frequency error testing the following variations were made:

	Category	***Nominal***	***Variation***
☒	Mains	110 V ac +/-2 %	85 % and 115 %
☐	Battery	New Battery	N/A

11 Radiated emissions below 30 MHz

11.1 Definitions

Out-of-band emissions
Emissions on a frequency or frequencies immediately outside the necessary bandwidth which result from the modulation process, but exclude spurious emissions.

Spurious emissions
Emissions on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Restricted bands
A frequency band in which intentional radiators are permitted to radiate only spurious emissions but not fundamental signals.

11.2 Test Parameters

Test Location:	Element Skelmersdale.
Test Chamber:	Chamber 1
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.4
Frequencies Measured:	13.56 MHz
Deviations From Standard:	None
Measurement Distance and Site:	10 m, OATS without ground plane.
EUT Height:	1 m
Measurement Antenna and Height:	60 cm shielded loop; 1 m
Measurement BW:	9 kHz to 150 kHz: 200 Hz; 150 kHz to 30 MHz: 9 kHz
Measurement Detector:	9 kHz to 90 kHz and 110 kHz to 490 kHz: Average, RMS Other frequencies below 30 MHz: Quasi-peak.

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 55 % RH	20 % RH to 75 % RH (as declared)
Supply:110 Vac	

11.3 Test Limit

Emissions from license-exempt transmitters shall comply with the field strength limits shown in the table below. Additionally, the level of any transmitter emission shall not exceed the level of the transmitter's fundamental emission.

General Field Strength Limits for License-Exempt Transmitters at Frequencies Below 30 MHz

Frequency, f (kHz)	*Field Strength*	*Measurement Distance (m)*
9 to 490	2,400 / 377.f (µA/m) 2,400 / f (µV/m)	300
490 to 1,750	24,000 / 377.f (µA/m) 24,000 / f (µV/m)	30
1,750 to 30,000	30 (µV/m)	30

n.b. Devices operated pursuant to §15.225 / RSS-210 A2.6 are exempt from complying with the restricted band requirements for the 13.36–13.41 MHz band only.

11.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure i, the EUT fundamental frequency was maximised by rotating the EUT through 360º, in three orthogonal planes, and adjusting the measurement antenna azimuth.

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst-case determined for function, operation, orientation, etc. for both vertical and horizontal polarisations. Pre-scan plots are shown with a peak detector and 9 kHz RBW.

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

Emissions between 9 kHz and 30 MHz are measured using a calibrated 60cm active loop antenna. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in µV/m at the regulatory distance, using:

$$FS = 10^{(PR - CF) / 20}$$

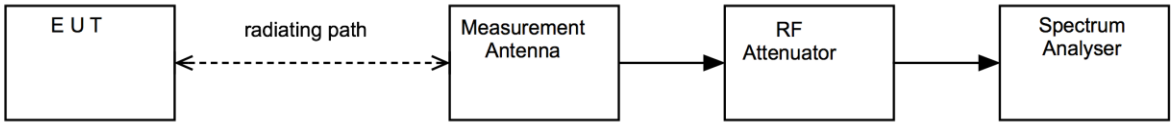
Where,

PR is the power recorded on the receiver / spectrum analyzer in dBµV and includes any cable loss, antenna factor and pre-amplifier gain;
CF is the distance extrapolation factor in dB (where measurement distance different to limit distance);

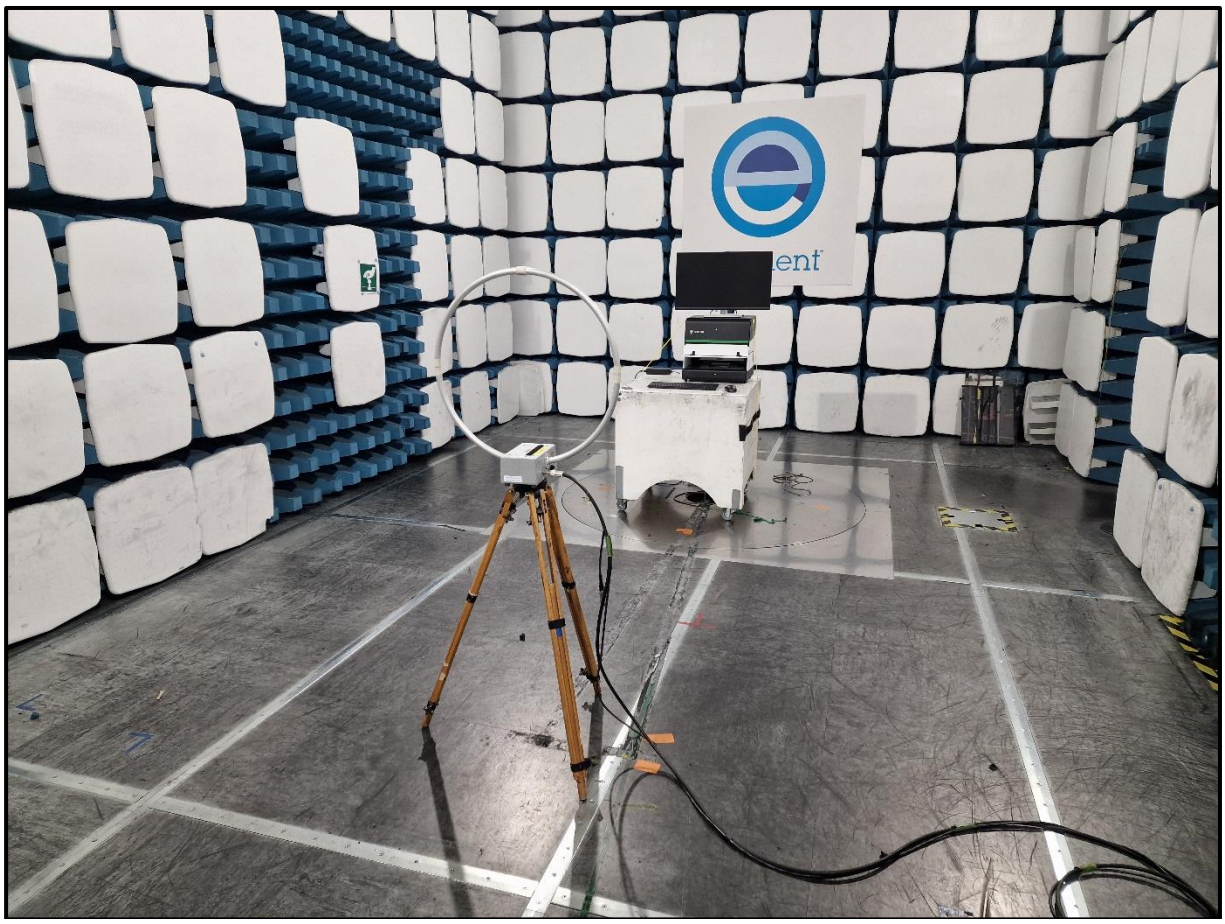
Per FCC 47CFR15.31(f)(2) / RSS-Gen 6.4, an extrapolation factor of 40 dB per decade was used for measurements at distances closer than specified.

This field strength value is then compared with the regulatory limit.

Figure i Test Setup



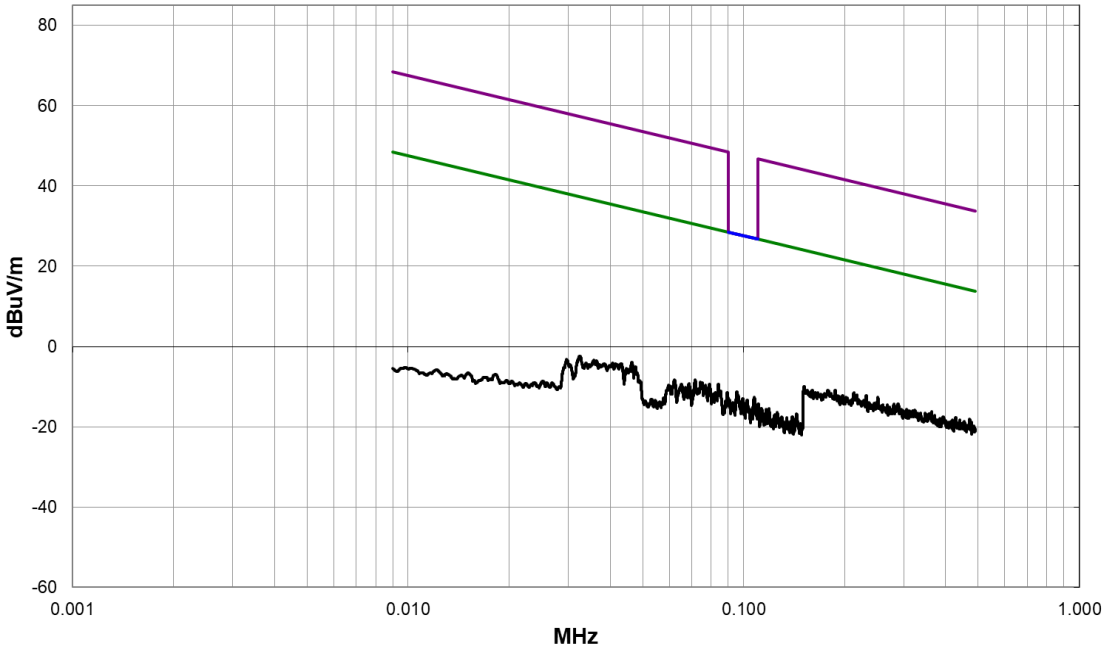
11.5 Test Set-up Photograph



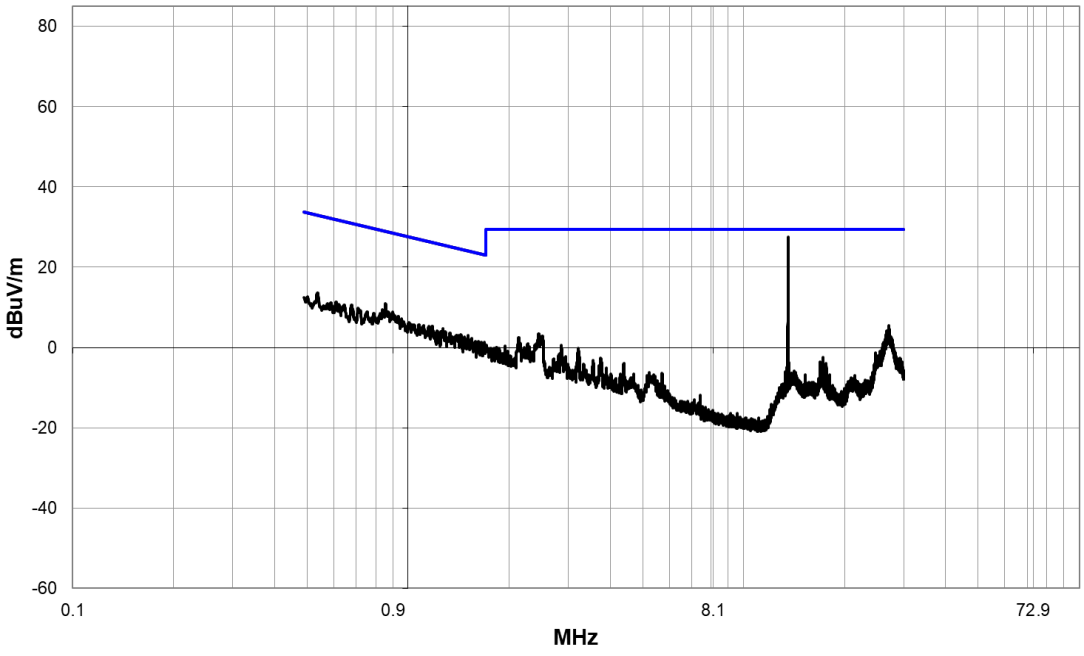
11.6 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
6502	EMCO	Active Loop Antenna	R0079	2025-10-10
ESR 7	R&S	Spectrum Analyser	U727	2025-05-17

11.7 Test Results



9 kHz to 490 kHz



490 kHz to 30 MHz

13.56 MHz						
Emission Frequency (MHz)	***Receiver Level (dBµV/m)***	***Measurement Distance (m)***	***Limit Distance (m)***	***Extrapolation Factor (dB)***	***Field Strength (µV/m)***	***Result***
No Significant Emissions						Pass

12 Radiated emissions

12.1 Definitions

Out-of-band emissions
Emissions on a frequency or frequencies immediately outside the necessary bandwidth which result from the modulation process, but exclude spurious emissions.

Spurious emissions
Emissions on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Restricted bands
A frequency band in which intentional radiators are permitted to radiate only spurious emissions but not fundamental signals.

12.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	REF940
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.5
Frequencies Measured:	13.56 MHz
Deviations From Standard:	None
Measurement BW:	30 MHz to 300 MHz: 120 kHz
Measurement Detector:	Quasi-peak

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 45.6 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 Vac	

12.3 Test Limit

Emissions from license-exempt transmitters shall comply with the field strength limits shown in the table below. Additionally, the level of any transmitter emission shall not exceed the level of the transmitter's fundamental emission.

General Field Strength Limits for License-Exempt Transmitters at Frequencies above 30 MHz

Frequency (MHz)	***Field Strength (µV/m at 3 m)***
30 to 88	100
88 to 216	150
216 to 960	200
Above 960	500

12.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure ii, the emissions from the EUT were measured on a spectrum analyzer / EMI receiver.

Radiated electromagnetic emissions from the EUT are checked first by preview scans. Preview scans for all spectrum and modulation characteristics are checked, using a peak detector and where applicable worst-case determined for function, operation, orientation, etc. for both vertical and horizontal polarisations. Pre-scan plots are shown with a peak detector and 100 kHz RBW.

If the EUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.10 are followed. Alternatively, a layout closest to normal use (as declared by the provider) is employed, (see EUT setup photographs for more detail).

Emissions between 30 MHz and 1 GHz are measured using calibrated broadband antennas. Emissions above 1 GHz are characterized using standard gain horn antennas. Pre-amplifiers and filters are used where required. Care is taken to ensure that test receiver resolution bandwidth, video bandwidth and detector type(s) meet the regulatory requirements.

For both horizontal and vertical polarizations, the EUT is then rotated through 360 degrees in azimuth until the highest emission is detected. At the previously determined azimuth the test antenna is raised and lowered from 1 to 4 m in height until a maximum emission level is detected, this maximum value is recorded.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in dBµV/m at the regulatory distance, using:

$$FS = PR + CL + AF – PA + DC – CF$$

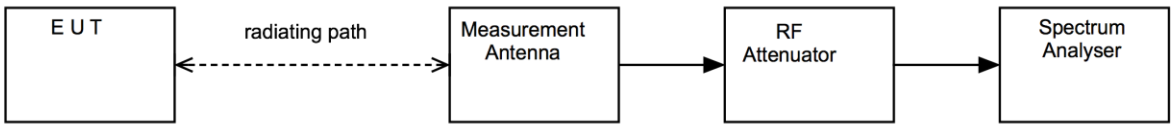
$$Factor = CL + AF – PA$$

Where,

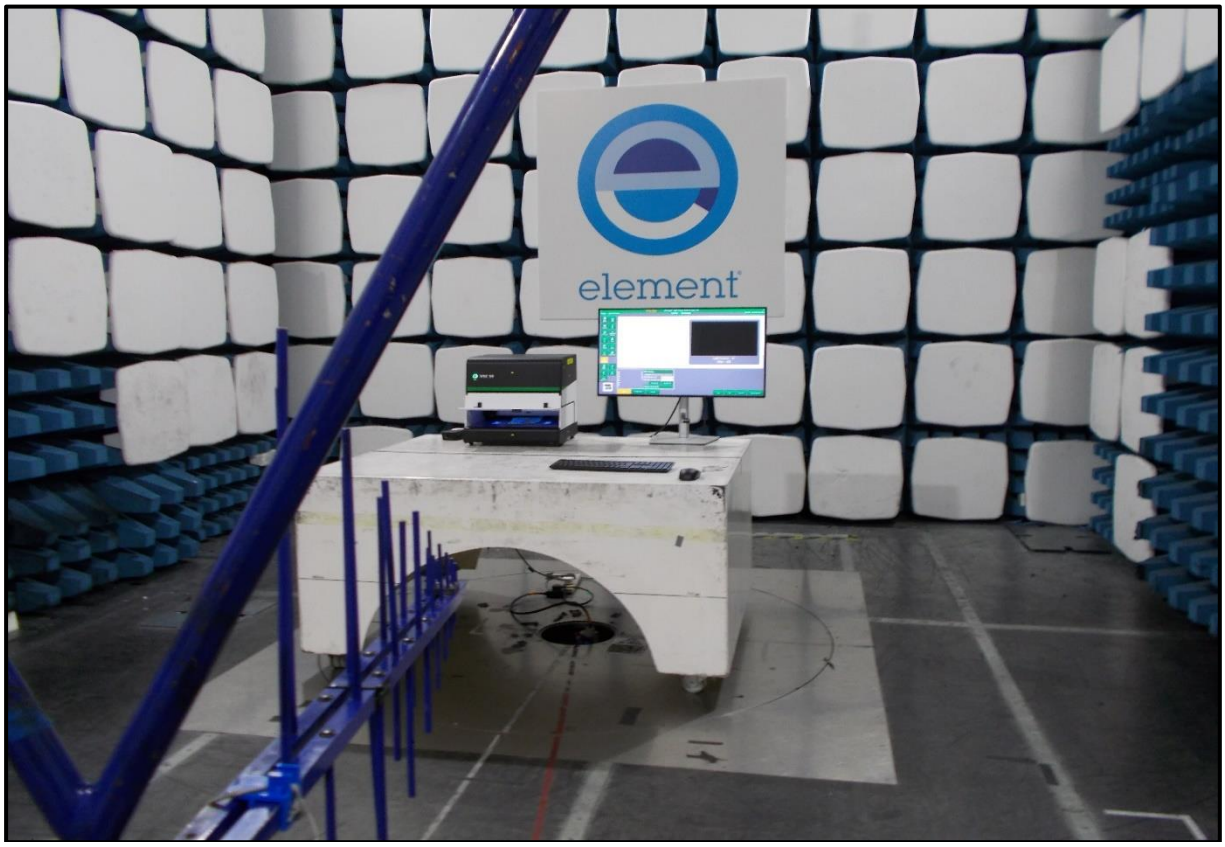
PR is the power recorded on the receiver / spectrum analyzer in dBµV;
CL is the cable loss in dB;
AF is the test antenna factor in dB/m;
PA is the pre-amplifier gain in dB (where used);
DC is the duty correction factor in dB (where used, e.g. harmonics of pulsed fundamental);
CF is the distance factor in dB (where measurement distance is different to limit distance);

This field strength value is then compared with the regulatory limit.

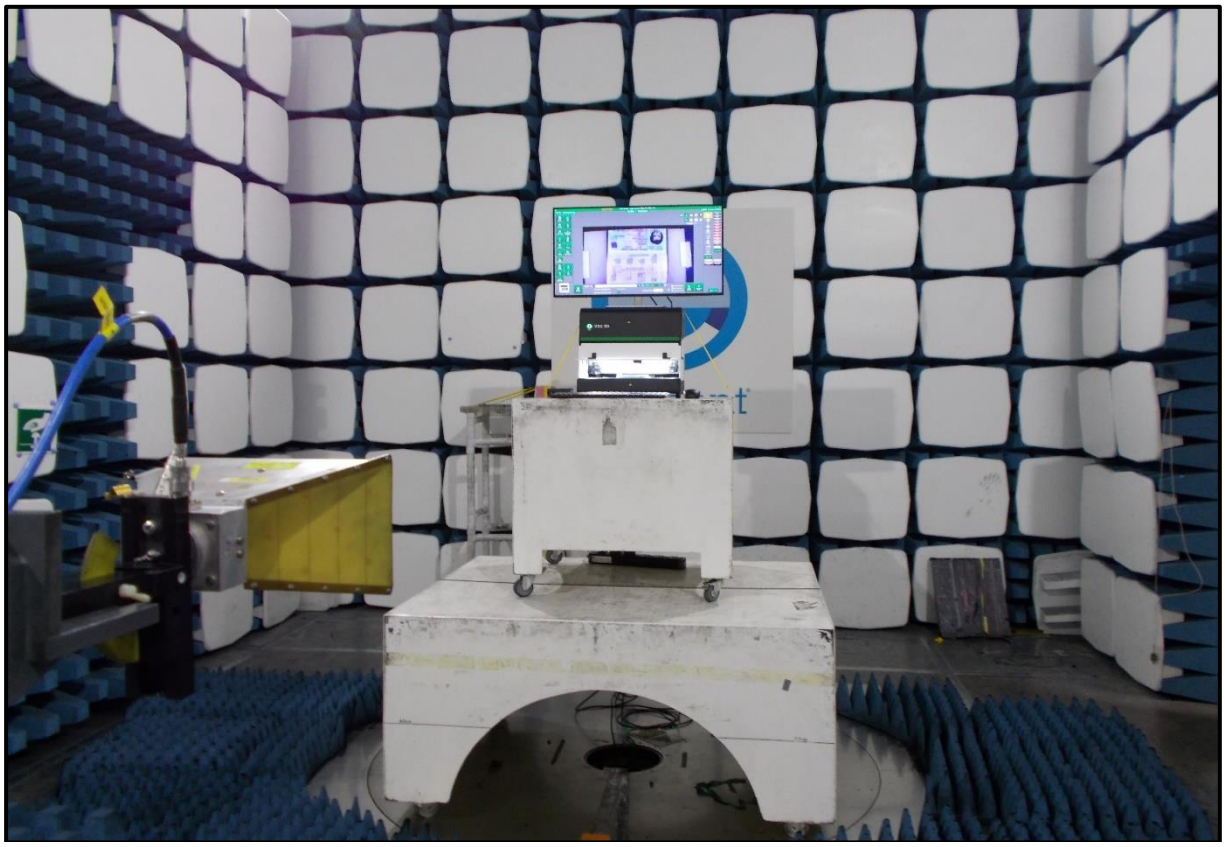
Figure ii Test Setup



12.5 Test Set-up Photographs



30 MHz to 1 GHz



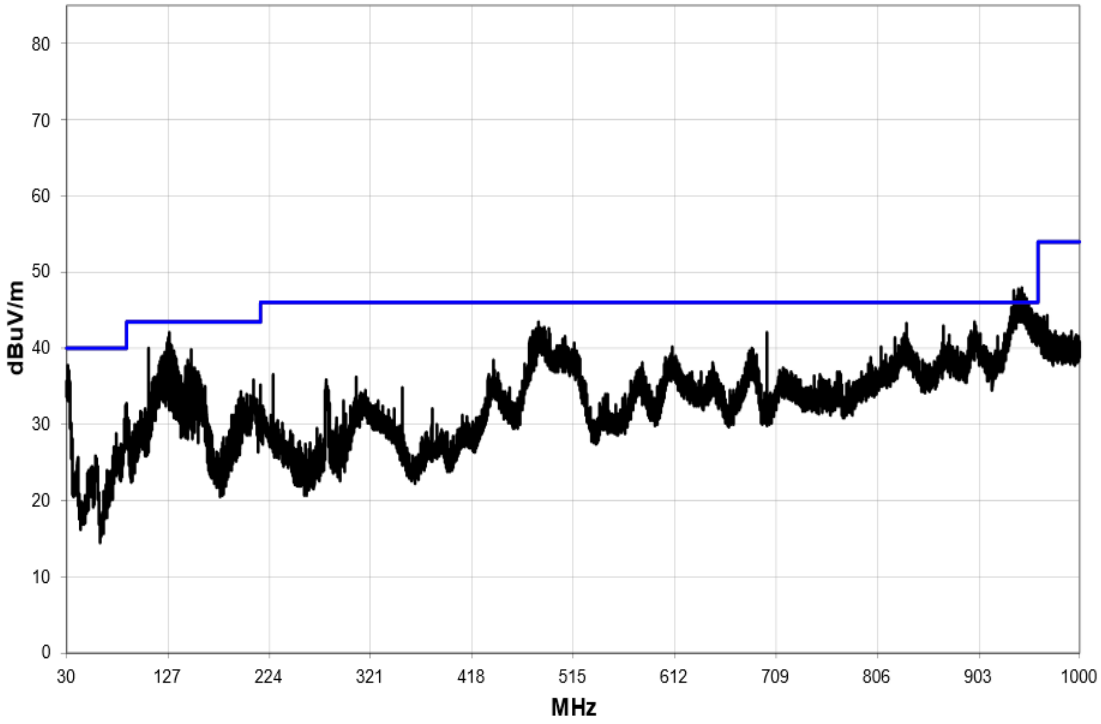
1 GHz to 7 GHz

12.6 Test Equipment

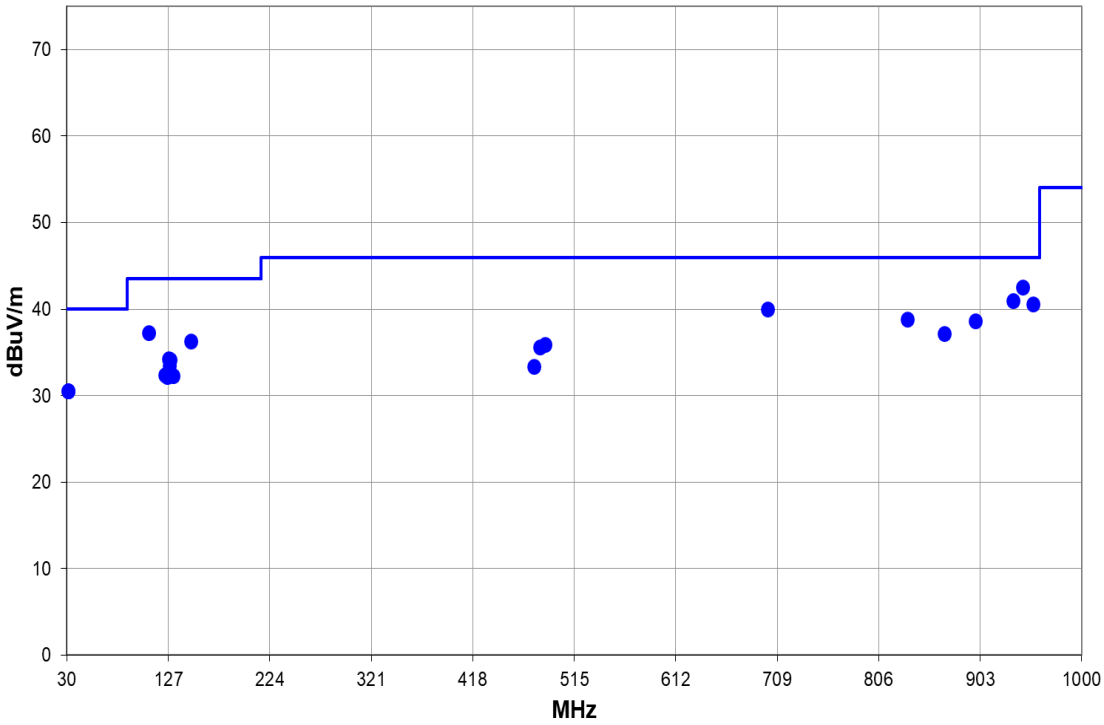
Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
CBL611/B	Chase	Bilog	U573	2024-10-14
ESR 7	R&S	Spectrum Analyser	U727	2025-05-17
6201-69	Watkins Johnson	PreAmp	U372	2025-03-15
3115	EMCO	1-18GHz Horn	U223	2026-01-17
8449B	Agilent	Pre Amp	L572	2024-10-30
FSW 43	R&S	Spectrum Analyser	U728	2025-06-12
LB-180400-25-C-KF*	A-INFO	26.5 GHz -40GHz Horn	REF 2245	2024-09-23

Note:* Was in calibration on the date of the test.

12.7 Test Results 30 MHz to 1 GHz



30 MHz to 1 GHz Scan

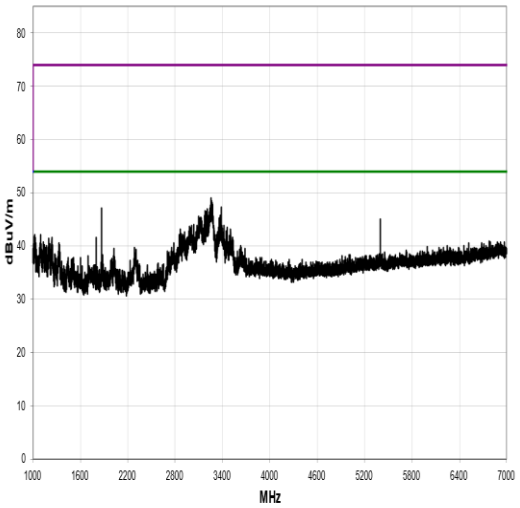


30 MHz to 1 GHz Maximised emissions

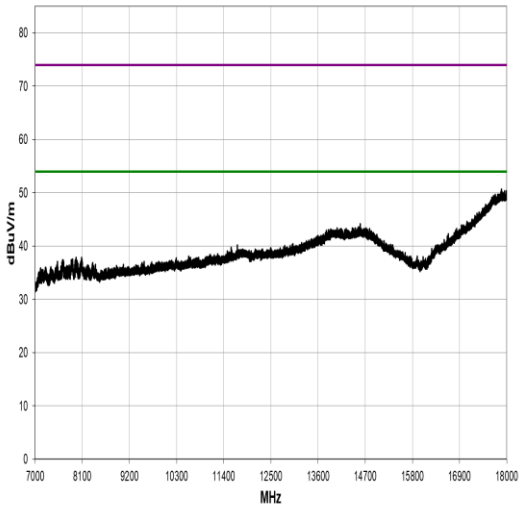
30 MHz to 1 GHz final measurement results

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
943.628	36.3	6.2	1.0	142.0	3.0	0.0	Horz	QP	0.0	42.5	46.0	-3.5
934.645	35.0	5.9	1.0	151.0	3.0	0.0	Horz	QP	0.0	40.9	46.0	-5.1
954.154	34.0	6.5	1.0	158.9	3.0	0.0	Horz	QP	0.0	40.5	46.0	-5.5
700.016	38.2	1.8	2.0	290.9	3.0	0.0	Horz	QP	0.0	40.0	46.0	-6.0
108.505	48.2	-11.0	3.99	69.0	3.0	0.0	Horz	QP	0.0	37.2	43.5	-6.3
833.663	34.5	4.3	2.0	185.1	3.0	0.0	Horz	QP	0.0	38.8	46.0	-7.2
149.186	46.4	-10.1	1.77	37.0	3.0	0.0	Vert	QP	0.0	36.3	43.5	-7.2
898.616	34.1	4.5	1.5	192.9	3.0	0.0	Horz	QP	0.0	38.6	46.0	-7.4
868.960	32.7	4.4	1.5	158.0	3.0	0.0	Horz	QP	0.0	37.1	46.0	-8.9
127.764	43.5	-9.3	1.49	198.1	3.0	0.0	Vert	QP	0.0	34.2	43.5	-9.3
128.981	43.4	-9.3	1.5	244.0	3.0	0.0	Vert	QP	0.0	34.1	43.5	-9.4
31.375	35.0	-4.5	1.0	156.0	3.0	0.0	Vert	QP	0.0	30.5	40.0	-9.5
31.632	35.1	-4.6	1.0	146.0	3.0	0.0	Vert	QP	0.0	30.5	40.0	-9.5
128.237	42.7	-9.3	1.5	283.0	3.0	0.0	Vert	QP	0.0	33.4	43.5	-10.1
487.143	37.6	-1.7	1.44	203.0	3.0	0.0	Horz	QP	0.0	35.9	46.0	-10.1
482.602	37.4	-1.8	1.0	96.0	3.0	0.0	Horz	QP	0.0	35.6	46.0	-10.4
124.463	41.9	-9.5	1.5	207.0	3.0	0.0	Vert	QP	0.0	32.4	43.5	-11.1
131.661	41.6	-9.3	1.5	198.9	3.0	0.0	Vert	QP	0.0	32.3	43.5	-11.2
126.023	41.6	-9.4	1.06	298.0	3.0	0.0	Vert	QP	0.0	32.2	43.5	-11.3
476.788	35.3	-2.0	1.0	103.9	3.0	0.0	Horz	QP	0.0	33.3	46.0	-12.7

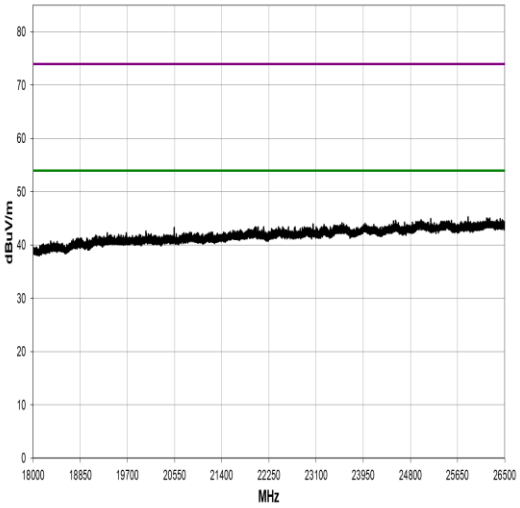
12.8 Test Results 1 GHz to 40 GHz



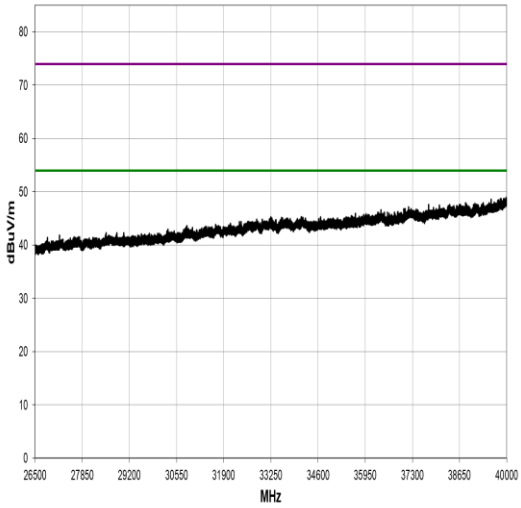
1 GHz to 7 GHz



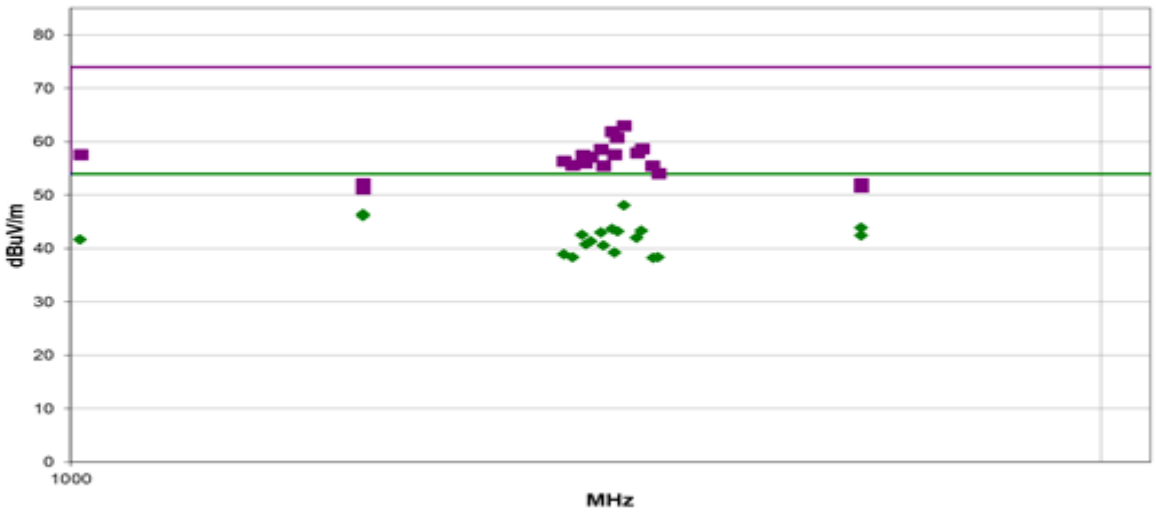
7 GHz to 18 GHz



18 GHz to 26.5 GHz



26.5 GHz to 40 GHz



1 GHz to 7 GHz maximised emissions

! GHz to 40 GHz final measurement results

Freq (MHz)	Amplitude (dBuV)	Factor (dB/m)	Antenna Height (meters)	Azimuth (degrees)	Test Distance (meters)	External Attenuation (dB)	Polarity/ Transducer Type	Detector	Distance Adjustment (dB)	Adjusted (dBuV/m)	Spec. Limit (dBuV/m)	Compared to Spec. (dB)
3257.631	48.9	-0.9	1.2	204.0	3.0	0.0	Horz	AV	0.0	48.0	54.0	-6.0
1866.208	52.3	-5.9	1.54	204.0	3.0	0.0	Vert	AV	0.0	46.4	54.0	-7.6
1866.208	52.0	-5.9	2.88	201.1	3.0	0.0	Horz	AV	0.0	46.1	54.0	-7.9
5400.258	40.7	3.2	1.46	156.0	3.0	0.0	Vert	AV	0.0	43.9	54.0	-10.1
3173.671	44.7	-1.1	1.77	202.0	3.0	0.0	Horz	AV	0.0	43.6	54.0	-10.4
3381.612	43.8	-0.5	2.09	202.9	3.0	0.0	Horz	AV	0.0	43.3	54.0	-10.7
3212.496	44.3	-1.1	1.3	213.1	3.0	0.0	Horz	AV	0.0	43.2	54.0	-10.8
3256.732	63.9	-0.9	1.2	204.0	3.0	0.0	Horz	PK	0.0	63.0	74.0	-11.0
3101.496	44.3	-1.3	1.36	202.0	3.0	0.0	Horz	AV	0.0	43.0	54.0	-11.0
2977.020	44.7	-2.2	1.96	216.9	3.0	0.0	Horz	AV	0.0	42.5	54.0	-11.5
5400.258	39.2	3.2	1.76	138.9	3.0	0.0	Horz	AV	0.0	42.4	54.0	-11.6
3346.544	42.6	-0.6	2.23	181.0	3.0	0.0	Horz	AV	0.0	42.0	54.0	-12.0
3174.561	63.0	-1.1	1.77	202.0	3.0	0.0	Horz	PK	0.0	61.9	74.0	-12.1
1021.103	53.0	-11.4	1.14	194.9	3.0	0.0	Horz	AV	0.0	41.6	54.0	-12.4
3033.929	43.1	-1.8	1.74	199.0	3.0	0.0	Horz	AV	0.0	41.3	54.0	-12.7
3209.226	61.9	-1.1	1.3	213.1	3.0	0.0	Horz	PK	0.0	60.8	74.0	-13.2
3001.496	42.8	-2.0	1.5	229.0	3.0	0.0	Vert	AV	0.0	40.8	54.0	-13.2
3118.496	41.8	-1.3	1.5	165.0	3.0	0.0	Vert	AV	0.0	40.5	54.0	-13.5
3192.701	40.3	-1.1	1.47	168.9	3.0	0.0	Vert	AV	0.0	39.2	54.0	-14.8
2865.496	41.8	-2.9	1.5	194.0	3.0	0.0	Horz	AV	0.0	38.9	54.0	-15.1
3383.759	59.0	-0.4	2.09	202.9	3.0	0.0	Horz	PK	0.0	58.6	74.0	-15.4
3098.709	59.8	-1.3	1.36	202.0	3.0	0.0	Horz	PK	0.0	58.5	74.0	-15.5
3501.795	38.6	-0.3	1.5	190.1	3.0	0.0	Horz	AV	0.0	38.3	54.0	-15.7
2919.687	40.9	-2.6	1.5	198.0	3.0	0.0	Horz	AV	0.0	38.3	54.0	-15.7
3463.155	38.6	-0.4	1.03	199.0	3.0	0.0	Horz	AV	0.0	38.2	54.0	-15.8
3349.057	58.5	-0.6	2.23	181.0	3.0	0.0	Horz	PK	0.0	57.9	74.0	-16.1
3191.669	58.7	-1.1	1.47	168.9	3.0	0.0	Vert	PK	0.0	57.6	74.0	-16.4
1022.127	68.9	-11.4	1.14	194.9	3.0	0.0	Horz	PK	0.0	57.5	74.0	-16.5
2980.381	59.6	-2.2	1.96	216.9	3.0	0.0	Horz	PK	0.0	57.4	74.0	-16.6
3035.559	58.9	-1.8	1.74	199.0	3.0	0.0	Horz	PK	0.0	57.1	74.0	-16.9
2865.396	59.2	-2.9	1.5	194.0	3.0	0.0	Horz	PK	0.0	56.3	74.0	-17.7
2997.835	58.1	-2.1	1.5	229.0	3.0	0.0	Vert	PK	0.0	56.0	74.0	-18.0
2920.328	58.2	-2.6	1.5	198.0	3.0	0.0	Horz	PK	0.0	55.6	74.0	-18.4
3460.567	55.9	-0.4	1.03	199.0	3.0	0.0	Horz	PK	0.0	55.5	74.0	-18.5
3116.150	56.8	-1.3	1.5	165.0	3.0	0.0	Vert	PK	0.0	55.5	74.0	-18.5
3504.716	54.3	-0.3	1.5	190.1	3.0	0.0	Horz	PK	0.0	54.0	74.0	-20.0
1866.125	58.0	-5.9	1.54	204.0	3.0	0.0	Vert	PK	0.0	52.1	74.0	-21.9
5399.992	48.9	3.2	1.46	156.0	3.0	0.0	Vert	PK	0.0	52.1	74.0	-21.9
5400.075	48.3	3.2	1.76	138.9	3.0	0.0	Horz	PK	0.0	51.5	74.0	-22.5
1865.884	57.0	-5.9	2.88	201.1	3.0	0.0	Horz	PK	0.0	51.1	74.0	-22.9

13 AC Powerline Line conducted emissions

13.1 Definition

Line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network.

13.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Transient chamber 2
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.2
Frequencies Measured:	13.56 MHz
EUT Modulation:	AM
Deviations From Standard:	None
Measurement BW:	9 kHz
Measurement Detectors:	Quasi-Peak and Average, RMS

Environmental Conditions (Normal Environment)

Temperature: 20 °C	+15 ºC to +35 ºC (as declared)
Humidity: 60 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 Vac	

13.3 Test Limit

A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz, shall not exceed the limits in Table 3.

Table 3 – AC Power Line Conducted Emission Limits

Frequency (MHz)	***Conducted limit (dBµV)***	
	Quasi-Peak	***Average****
0.15 to 0.5	66 to 56*	56 to 46*
0.5 to 5	56	46
5 to 30	60	50

*The level decreases linearly with the logarithm of the frequency.
**A linear average detector is required.

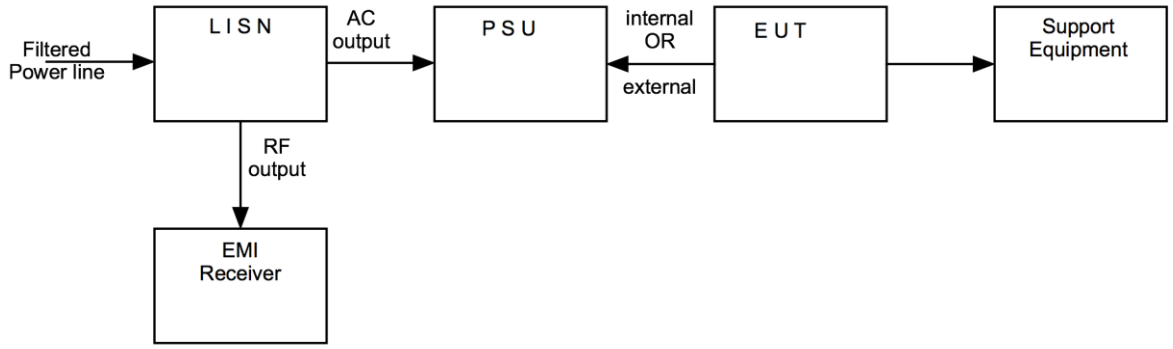
13.4 Test Method

With the EUT setup in a screened room, as per section 9 of this report and connected as per Figure iii, the power line emissions were measured on a spectrum analyzer / EMI receiver.

AC power line conducted emissions from the EUT are checked first by preview scans with peak and average detectors covering both live and neutral lines. A spectrum analyzer is used to determine if any periodic emissions are present.

Formal measurements using the correct detector(s) and bandwidth are made on frequencies identified from the preview scans. Final measurements were performed with EUT set at its maximum duty in transmit and receive modes.

Figure iii Test Setup

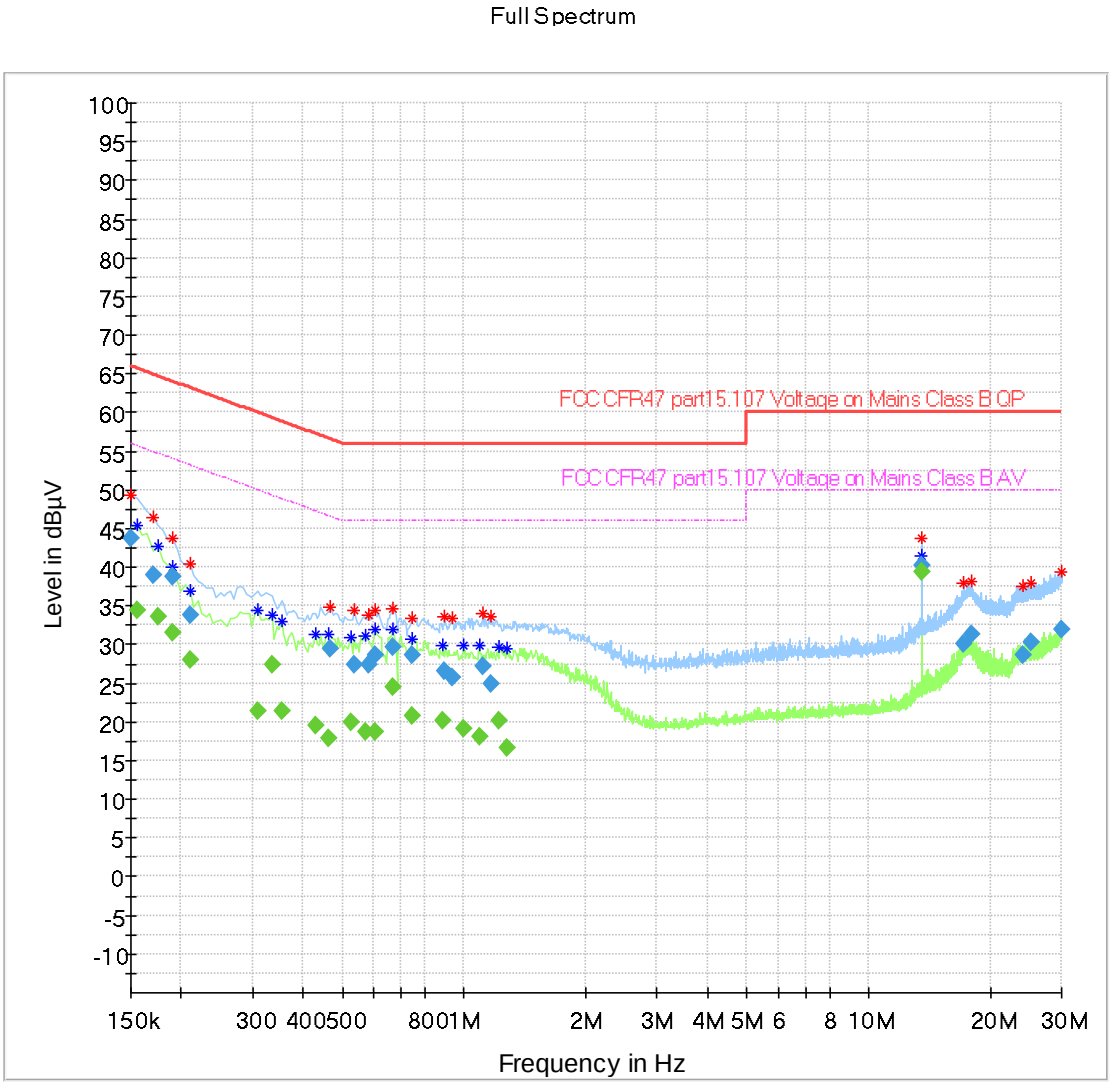


13.5 Test Set-up Photograph

13.6 Test Equipment

Equipment Type	Manufacturer	Equipment Description	Element No	Due For Calibration
EMI Receiver	R&S	ESR7	U456	2025-03-08
ENV216	R&S	Lisn	U396	2025-05-16
ESH3-Z2	R&S	Pulse Limiter 0-30MHz	U559	2025-02-12
AA1000F	Takasgo	Power Supply	PSU10	Use REF976
Multimeter	Agilent	34405a	REF976	2025-01-26

13.7 Test Results



Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	Filter	Corr. (dB)
0.150000	43.69	---	66.00	22.31	5000.0	9.000	L1	OFF	19.6
0.154975	---	34.46	55.73	21.27	5000.0	9.000	L1	OFF	19.6
0.169900	39.00	---	64.97	25.96	5000.0	9.000	L1	OFF	19.6
0.174875	---	33.53	54.73	21.20	5000.0	9.000	L1	OFF	19.6
0.189800	38.72	---	64.05	25.32	5000.0	9.000	L1	OFF	19.6
0.189800	---	31.48	54.05	22.57	5000.0	9.000	L1	OFF	19.6
0.209700	---	28.01	53.22	25.21	5000.0	9.000	L1	OFF	19.6
0.209700	33.73	---	63.22	29.49	5000.0	9.000	L1	OFF	19.6
0.309200	---	21.47	49.99	28.52	5000.0	9.000	L1	OFF	19.6
0.334075	---	27.33	49.35	22.01	5000.0	9.000	L1	OFF	19.6
0.353975	---	21.40	48.87	27.47	5000.0	9.000	L1	OFF	19.6
0.428600	---	19.59	47.28	27.69	5000.0	9.000	L1	OFF	19.6
0.463425	---	17.99	46.63	28.64	5000.0	9.000	L1	OFF	19.6
0.468400	29.48	---	56.54	27.06	5000.0	9.000	L1	OFF	19.6
0.523125	---	19.99	46.00	26.01	5000.0	9.000	L1	OFF	19.6
0.533075	27.36	---	56.00	28.64	5000.0	9.000	L1	OFF	19.6
0.572875	---	18.82	46.00	27.18	5000.0	9.000	L1	OFF	19.7
0.582825	27.40	---	56.00	28.60	5000.0	9.000	L1	OFF	19.7
0.602725	---	18.76	46.00	27.24	5000.0	9.000	L1	OFF	19.7
0.602725	28.71	---	56.00	27.29	5000.0	9.000	L1	OFF	19.7
0.667400	---	24.56	46.00	21.44	5000.0	9.000	L1	OFF	19.7
0.667400	29.62	---	56.00	26.38	5000.0	9.000	L1	OFF	19.7
0.747000	28.58	---	56.00	27.42	5000.0	9.000	L1	OFF	19.7
0.747000	---	20.86	46.00	25.14	5000.0	9.000	L1	OFF	19.7
0.886300	---	20.07	46.00	25.93	5000.0	9.000	N	OFF	19.7
0.896250	26.62	---	56.00	29.38	5000.0	9.000	L1	OFF	19.7
0.931075	25.82	---	56.00	30.18	5000.0	9.000	L1	OFF	19.7
0.995750	---	19.11	46.00	26.89	5000.0	9.000	N	OFF	19.7
1.090275	---	18.10	46.00	27.90	5000.0	9.000	N	OFF	19.7
1.115150	27.18	---	56.00	28.82	5000.0	9.000	L1	OFF	19.7
1.159925	24.87	---	56.00	31.13	5000.0	9.000	L1	OFF	19.7
1.224600	---	20.22	46.00	25.78	5000.0	9.000	N	OFF	19.7
1.274350	---	16.60	46.00	29.40	5000.0	9.000	N	OFF	19.7
13.557625	---	39.49	50.00	10.51	5000.0	9.000	N	OFF	20.5
13.557625	40.16	---	60.00	19.84	5000.0	9.000	N	OFF	20.5
17.244100	30.01	---	60.00	29.99	5000.0	9.000	N	OFF	20.8
17.985375	31.43	---	60.00	28.57	5000.0	9.000	N	OFF	20.9
24.179250	28.60	---	60.00	31.40	5000.0	9.000	L1	OFF	20.8
25.154350	30.27	---	60.00	29.73	5000.0	9.000	L1	OFF	20.8
29.875625	31.94	---	60.00	28.06	5000.0	9.000	L1	OFF	20.8

14 Occupied Bandwidth

14.1 Definition

20 dB bandwidth
The emission bandwidth (x dB) is defined as the frequency range between two points, one above and one below the carrier frequency, at which the spectral density of the emission is attenuated x dB below the maximum in-band spectral density of the modulated signal.

14.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Lboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.9
Frequencies Measured:	13.56 MHz
EUT Test Modulations:	AM
Deviations From Standard:	None
Measurement BW: (requirement: 1% to 5% OBW) Spectrum Analyzer Video BW: (requirement at least 3x RBW) Measurement Span: (requirement 2 to 5 times OBW)	 1 kHz 3 kHz 20 kHz
Measurement Detector:	Peak

Environmental Conditions (Normal Environment)

Temperature: 20 °C	+15 ºC to +35 ºC (as declared)
Humidity:45 % RH	20 % RH to 75 % RH (as declared)
Supply: 110 Vac	

14.3 Test Limit

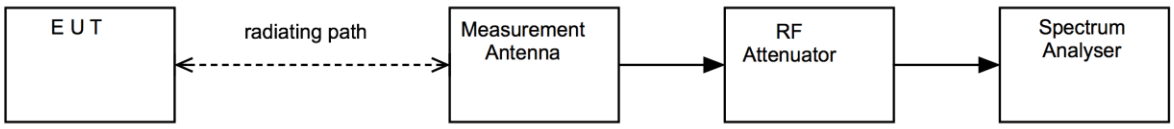
Federal Communications Commission:
Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated.

14.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure iv, the bandwidth of the EUT was measured on a spectrum analyser.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Figure iv Test Setup

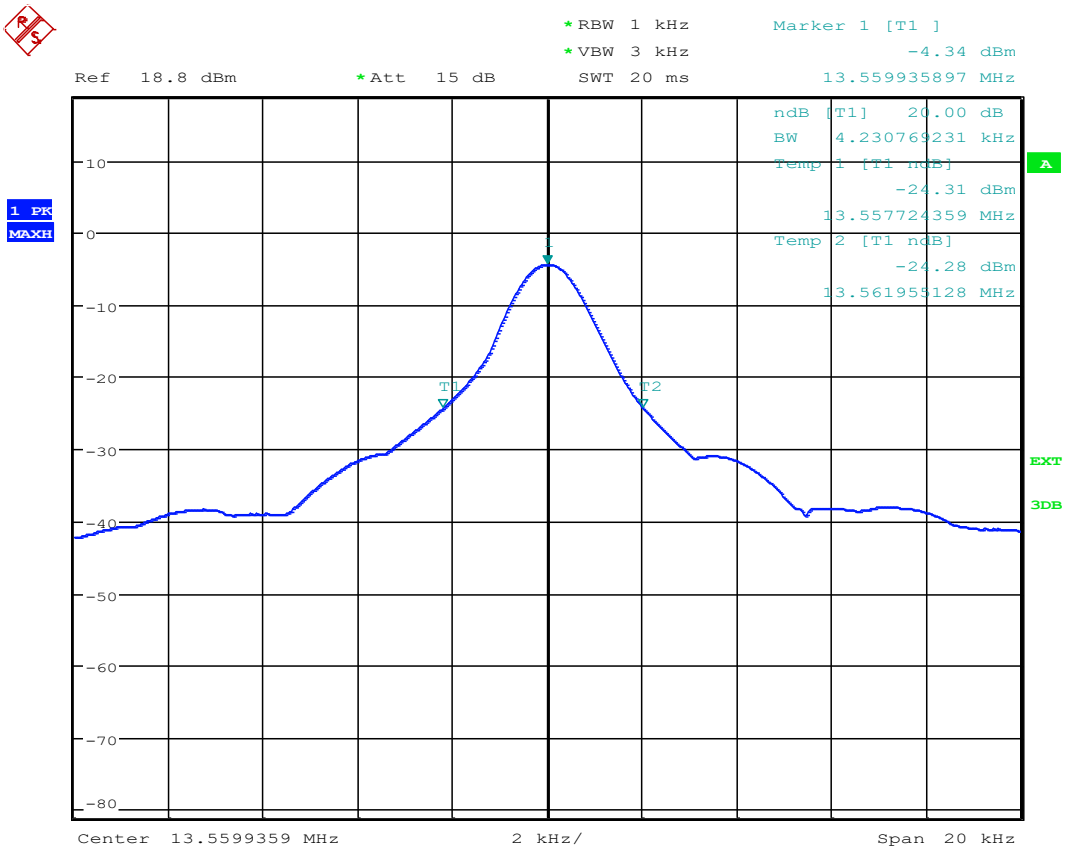


14.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
6502	EMCO	Active Loop Antenna	R0079	2025-10-10
ESR 7	R&S	Spectrum Analyser	U727	2025-05-17

14.6 Test Results

13.56 MHz			
Channel Frequency (MHz)	**F_L (MHz)**	**F_H (MHz)**	**20 dB Bandwidth (kHz)**
13.56	13.557724	13.561955	4.23



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15 Transmitter output power (fundamental radiated emission)

15.1 Definition

The RF power dissipated in the standard output termination when operating under the rated duty cycle selected by the applicant for approval.

15.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	OATS
Test Antenna:	Active 60cm loop
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.3 / 6.4
Frequencies Measured:	13.56 MHz
Deviations From Standard:	None
Measurement BW:	9 kHz
Measurement Detector:	Quasi-peak
Voltage Extreme Environment Test Range:	Mains Power = 85% and 115% of Nominal (FCC only requirement); Battery Power = new battery.

Environmental Conditions (Normal Environment)

Temperature: 22 °C	+15 ºC to +35 ºC (as declared)
Humidity: 55 % RH	20 % RH to 75 % RH (as declared)

15.3 Test Limit

The field strength measured at 30 m shall not exceed the limits in the following table:

Field Strength Limits for License-Exempt Transmitters for Any Application

Frequency range (MHz)	*Field strength (µV/m at 30m)*	*Field strength (dBµV/m at 30m)*
13.110 – 13.410	106	40.5
13.410 – 13.553	334	50.5
13.553 – 13.567	15,848	84.0
13.567 – 13.710	334	50.5
13.710 – 14.010	106	40.5

15.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, the resolution bandwidth of the spectrum analyser was increased above the EUT occupied bandwidth and the peak emission data noted.

The measurements were performed with EUT set at its maximum duty. All modulation schemes, data rates and power settings were used to observe the worst-case configuration in each bandwidth.

Power values measured on the test receiver / analyzer are converted to field strength, FS, in µV/m at the regulatory distance, using:

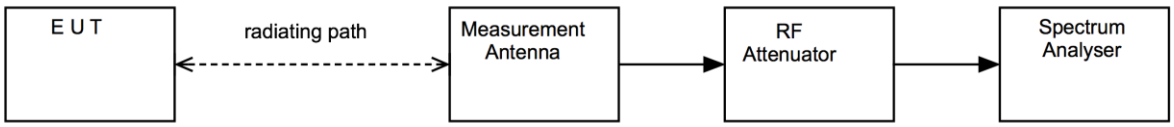
$$FS = 10^{(PR - CF) / 20}$$

Where,

PR is the power recorded on the receiver / spectrum analyzer in dBµV and includes any cable loss, antenna factor and pre-amplifier gain;
CF is the distance extrapolation factor in dB (where measurement distance different to limit distance);

This field strength value is then compared with the regulatory limit.

Figure v Test Setup

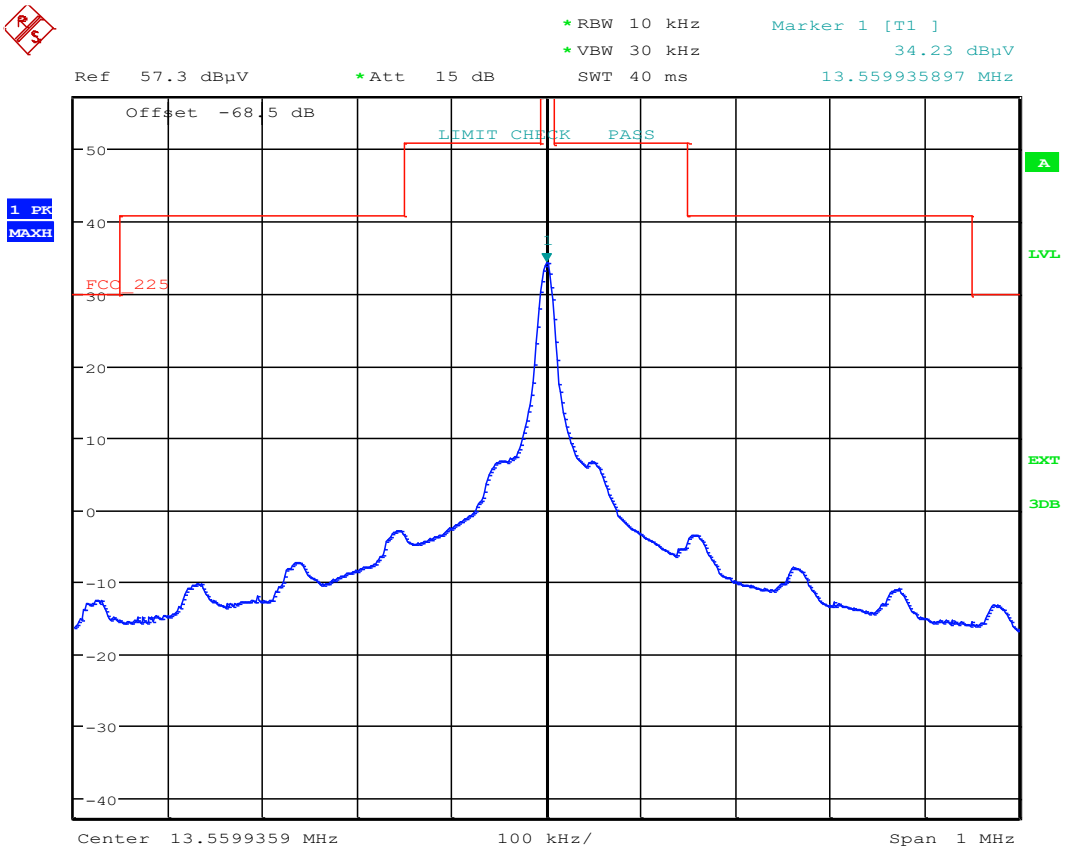


15.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
ESR7	R&S	EMI Receiver	U456	2025-03-08
6502	EMCO	Active Loop Antenna	R0079	2025-11-10

15.6 Test Results

13.56 MHz								
Channel Frequency (MHz)	***Receiver Level (dBµV/m)***	***Measurement Distance (m)***	***Limit Distance (m)***	***Extrapolation Factor (dB)***	***Field Strength (dBµV/m)***	***Result (µV/m)***	***Limit (µV/m)***	***Result***
13.56 MHz	53.34	10	30	19.08	34.26	51.642	15848	Pass



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16 Frequency stability

16.1 Definition

Frequency stability is a measure of frequency drift due to temperature and supply voltage variations, with reference to the frequency measured at an appropriate reference temperature and the rated supply voltage.

16.2 Test Parameters

Test Location:	Element Skelmersdale
Test Chamber:	Radio Laboratory
Test Standard and Clause:	ANSI C63.10-2013, Clause 6.8
Frequency Measured:	13.56 MHz
Modulation:	Off
Deviations From Standard:	None
Temperature Extreme Environment Test Range:	-20 to +50 C
Voltage Extreme Environment Test Range:	Mains Power = ±15% of Nominal;

Environmental Conditions (Normal Environment)

Temperature: 20 °C	Standard Requirement: +20 ºC
Humidity: 22.7 %RH	20 % RH to 75 % RH (as declared)

16.3 Test Limit

Carrier frequency stability shall be maintained to ±0.01% (±100 ppm).

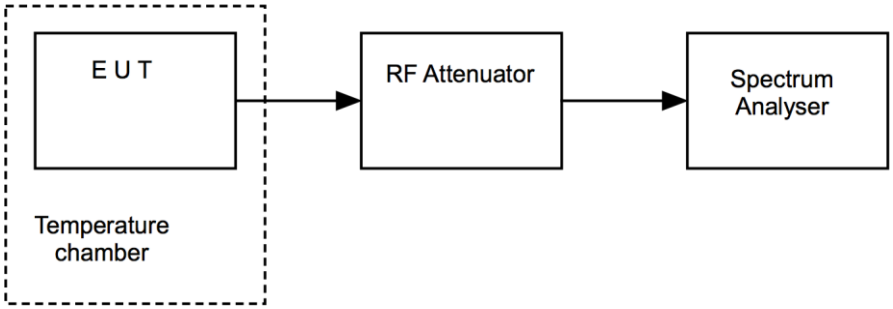
16.4 Test Method

With the EUT setup as per section 9 of this report and connected as per Figure v, the frequency was measured under varying conditions of temperature and supply voltage.

The measurements were performed with EUT Transmitting with a sample in place.

Measurements were made once temperature stability was achieved at each temperature.

Figure v Test Setup



16.5 Test Equipment

Equipment Type	*Manufacturer*	*Equipment Description*	*Element No*	*Due For Calibration*
FSU50	R&S	Spectrum Analyser	U544	2024-11-28
52 Series II	Fluke	Temperature Indicator	L426	2025-08-08
PCR 4000L	KiKusui	Power Supply	U580	Use Ref 976
ETS	ETS-S1000CHS	Temperature Chamber	U522	Use L426 Or U720
34405a	Agilent	Multimeter	REF976	2025-01-26

16.6 Test Results

EUT Frequency: 13.56 MHz					
Test Environment		***Measured Frequency (MHz)***	***Frequency error (kHz)***	***Frequency error (%)***	***Result***
-20 C	$V_{nominal}$	13.559929	0.027	0.00020	Pass
-10 C	$V_{nominal}$	13.559949	0.047	0.00035	Pass
0 C	$V_{nominal}$	13.559951	0.049	0.00036	Pass
+10 C	$V_{nominal}$	13.559924	0.075	0.00055	Pass
+20 C	$V_{minimum}$	13.559890	0.012	0.00009	Pass
	$V_{nominal}$	13.559902	N/A	N/A	N/A
	$V_{maximum}$	13.559892	0.01	0.00007	Pass
+30 C	$V_{nominal}$	13.559870	0.032	0.00024	Pass
+40 C	$V_{nominal}$	13.559845	0.057	0.00042	Pass
+50 C	$V_{nominal}$	13.559827	0.075	0.00055	Pass

17 Measurement Uncertainty

Radio Testing – General Uncertainty Schedule

All statements of uncertainty are expanded standard uncertainty using a coverage factor of 1.96 to give a 95 % confidence where no required test level exists.

Test/Measurement	***Budget Number***	***MU***
Conducted RF Power, Power Spectral Density, Adjacent Channel Power and Spurious emissions		
Absolute RF power (via antenna connecter) Sampling Power Meter to 8 GHz	MU4001	**0.9 dB**
Carrier Power and PSD - Spectrum Analysers	MU4004	**1.7 dB**
Adjacent Channel Power	MU4002	**1.9 dB**
Transmitter conducted spurious emissions (Including emissions due to intermodulation)	MU4041	**0.9 dB**
Conducted power and spurious emissions 40 GHz to 50 GHz	MU4042	**2.4 dB**
Conducted power and spurious emissions 50 GHz to 75 GHz	MU4043	**2.5 dB**
Conducted power and spurious emissions 75 GHz to 110 GHz	MU4044	**2.4 dB**
Radiated RF Power and Spurious emissions ERP and EIRP		
Effective Radiated Power Reverb Chamber	MU4020	**3.7 dB**
Effective Radiated Power	MU4021	**4.7 dB**
TRP Emissions 30 MHz to 1 GHz using CBL6111 or CBL6112 Bilog Antenna	MU4046	**5.3 dB**
TRP Emissions 1 GHz to 18 GHz using HL050 Log Periodic Antenna	MU4047	**5.1 dB**
TRP Emissions 18 GHz to 26.5 GHz using Standard Gain Horn	MU4048	**2.7 dB**
TRP Emissions 26.5 GHz to 40 GHz using Standard Gain Horn	MU4049	**2.7 dB**
In-band (3450-3650 MHz) TRP using CATR_ASH_B2	MU4051	**4.1 dB**
Cellular Radiated Spurious Emissions in a SAC 30 MHz to 180 MHz	MU4052	**6.3 dB**
Cellular Radiated Spurious Emissions in a SAC 180 MHz to 18 GHz	MU4052	**3.6 dB**
Cellular Radiated Spurious Emissions in a FAR 30 MHz to 180 MHz	MU4052	**5.4 dB**
Cellular Radiated Spurious Emissions in a FAR 180 MHz to 18 GHz	MU4052	**3.0 dB**
Spurious Emissions Electric and Magnetic Field		
Radiated Spurious Emissions 30 MHz to 1 GHz (Including emissions due to intermodulation)	MU4037	**4.8 dB**
Radiated Spurious Emissions 1-18 GHz (Including emissions due to intermodulation)	MU4032	**4.5 dB**
E Field Emissions 18 GHz to 26 GHz	MU4024	**3.2 dB**
E Field Emissions 26 GHz to 40 GHz	MU4025	**3.3 dB**
E Field Emissions 40 GHz to 50 GHz	MU4026	**3.5 dB**
E Field Emissions 50 GHz to 75 GHz	MU4027	**3.6 dB**
E Field Emissions 75 GHz to 110 GHz	MU4028	**3.6 dB**
Radiated Magnetic Field Emissions	MU4031	**2.3 dB**

Test/Measurement	***Budget Number***	***MU***
Frequency Measurements		
Frequency Deviation	MU4022	**3.7 kHz**
Frequency error using CMTA test set	MU4023	**113.441 Hz**
Frequency error using GPS locked frequency source	MU4045	**0.0413 ppm**
Bandwidth/Spectral Mask Measurements		
Channel Bandwidth	MU4005	**3.87%**
Transmitter Mask Amplitude	MU4039	**1.3 dB**
Transmitter Mask Frequency	MU4040	**2.59%**
Time Domain Measurements		
Transmission Time	MU4038	**4.40%**
Dynamic Frequency Selection (DFS) Parameters)		
DFS Analyser - Measurement Time	MU4006	**678.984 µs**
DFS Generator - Frequency Error	MU4007	**91.650 Hz**
DFS Threshold Conducted	MU4008	**1.3 dB**
DFS Threshold Radiated	MU4009	**3.2 dB**
Receiver Parameters		
EN 300 328 Receiver Blocking	MU4010	**1.1 dB**
EN 301 893 Receiver Blocking	MU4011	**1.1 dB**
EN 303 340 Adjacent Channel Selectivity	MU4012	**1.1 dB**
EN 303 340 Overloading	MU4013	**1.1 dB**
EN 303 340 Receiver Blocking	MU4014	**1.1 dB**
EN 303 340 Receiver Sensitivity	MU4015	**0.9 dB**
EN 303 372-1 Image Rejection	MU4016	**1.4 dB**
EN 303 372-1 Receiver Blocking	MU4017	**1.1 dB**
EN 303 372-2 Adjacent Channel Selectivity	MU4018	**1.1 dB**
EN 303 372-2 Dynamic Range	MU4019	**0.9 dB**
Receiver Blocking Talk Mode Conducted	MU4033	**1.2 dB**
Receiver Blocking Talk Mode- radiated	MU4034	**3.4 dB**
Rx Blocking, listen mode, blocking level	MU4035	**3.2 dB**
Rx Blocking, listen mode, radiated Threshold Measurement	MU4036	**3.4 dB**
Adjacent Sub Band Selectivity	MU4003	**4.2 dB**

Test/Measurement	***Budget Number***	***MU***
Rohde & Schwarz TS8997		
Carrier frequency	MU4050	**5.2 ppm**
RF Output Power	MU4050	**1.0 dB**
Peak Power	MU4050	**0.8 dB**
Power Spectral Density	MU4050	**1.0 dB**
Occupied Channel Bandwidth	MU4050	**2.08 %**
Transmitter unwanted emissions in-band	MU4050	**0.9 dB**
Transmitter unwanted emissions in the spurious domain 30 MHz to 1 GHz	MU4050	**0.6 dB**
Transmitter unwanted emissions in the spurious domain 1 GHz to 12.75 GHz	MU4050	**1.8 dB**
Receiver Spurious emission 30 MHz to 1 GHz	MU4050	**0.6 dB**
Receiver Spurious emission 1 GHz to 12.75 GHz	MU4050	**1.8 dB**
Duty Cycle	MU4050	**0.02 %**
Tx Sequence	MU4050	**0.02 %**
Tx Gap	MU4050	**0.02 %**
Medium Utilisation	MU4050	**0.1 %**
Accumulated Transmit Time	MU4050	**0.01 %**
Minimum Frequency Occupation Time	MU4050	**0.01 %**
Hopping Frequency Separation	MU4050	**0.6 %**
Receiver blocking (for bit streams)	MU4050	**3.0 dB**
Channel Access Mechanism / Adaptivity / DFS / Contention Based Protocol	MU4050	**1.8 dB**